

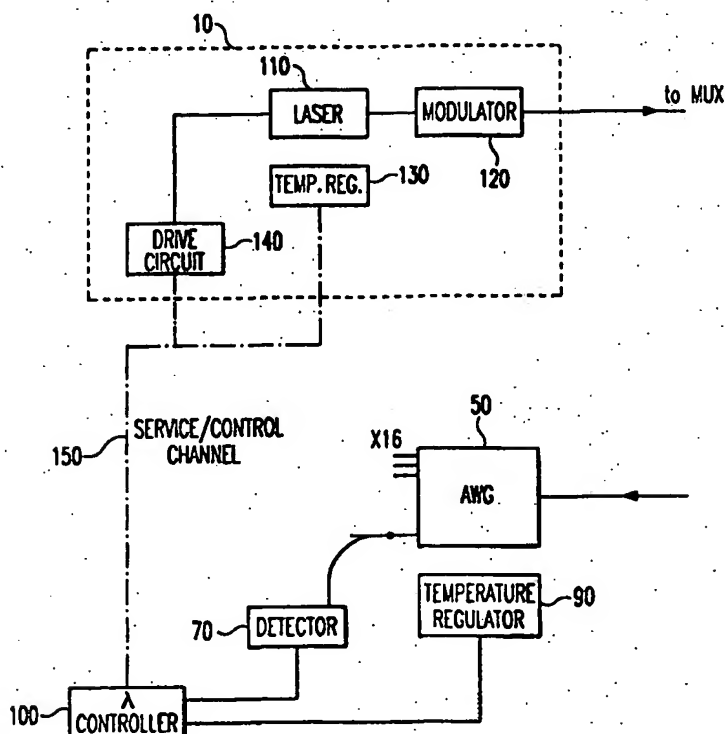


## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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**(54) Title:** WAVELENGTH CONTROL IN OPTICAL WDM SYSTEMS**(57) Abstract**

Wavelength drift in an optical WDM system between wavelengths launched by lasers (110) and received at a demultiplexer (50) can lead to disturbance of traffic signals if not identified and rectified rapidly. It is proposed to identify wavelength drift by determining a difference in temperature of the demultiplexer (50) for each channel between an actual temperature and a temperature for optimal transmission of the channel. The mean of these temperature differences for all channels is indicative of wavelength drift, while each difference is utilised to determine whether an individual channel is drifting in wavelength and to correct the drift. Wavelength drift can be detected and corrected where sourced at a laser (110) or due to a temperature variation at the demultiplexer (50). Measurement and control can be performed during normal operation without impeding or degrading traffic flow. Wavelength influencing parameters other than temperature can be utilized.



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Wavelength control in Optical WDM systems

## 1. Field of the Invention

10 The invention relates to wavelength division multiplexed optical communication systems and, in particular, to the measurement and control of wavelengths transmitted by an optical transmission source and received by an optical  
15 wavelength selective element.

## 2. Background Art

20 In wavelength division multiplexed (WDM) optical communication systems, a single fibre optic cable carries a plurality of optical signal channels, each channel being assigned a particular carrier wavelength. The signal channels are generated using wavelength specific lasers. These channels are then coupled to the traffic  
25 fibre using an optical combiner or multiplexer and sent to the next node in the system, possibly via a number of optical amplifiers. At the receiving node, the different wavelengths are filtered out in a demultiplexer and are sent to a respective receiver where they are converted to  
30 electrical signals and relayed to further systems or networks.

35 In the demultiplexer, individual optical channels must be selected from the multiplexed optical signal. To ensure that an optical signal is properly selected, the carrier wavelength launched by the laser transmitter must accurately match the wavelength selected in the demultiplexer. Although the lasers are generally very stable in terms of wavelength, erroneous operation can

5       lead to wavelength drift in an individual channel over  
time. Similarly, the wavelengths of the demultiplexer  
passbands can drift. It is important that this wavelength  
drift is detected and corrected before the channel has  
10       deteriorated so much that traffic is disturbed in the  
channel itself as a result of attenuation, and in  
neighbouring channels by crosstalk. This is particularly  
important for dense WDM systems wherein the wavelength  
spacing between channels is very small, often of the  
order of a nanometer.

15       A technique for dynamically stabilising a wavelength  
selective element in a WDM system is described in US-A-5  
673 129. This document describes that a wavelength  
reference is used to stabilise the output wavelength of a  
20       transmission laser while the reflection wavelength of a  
Bragg grating used as a wavelength selective element at  
the receiving end of the system is dynamically adjusted  
to obtain the maximum reflected optical signal and so  
accurately correlate the Bragg grating to the  
25       corresponding transmitted wavelength. The adjustment of  
the Bragg grating reflection wavelength is obtained by  
temperature tuning or adjustment of the amount of  
physical tension applied to the Bragg grating.

30       While this arrangement ensures the accurate correlation  
of the wavelength selective element to the transmitted  
wavelength, an extreme drift in wavelength in an  
individual laser will not be corrected and could  
ultimately lead to crosstalk between adjacent channels.  
35       Furthermore, the need for a wavelength reference for each  
laser necessitates the provision of a relatively large  
number of potentially costly components.

5 In an alternative embodiment described in the same patent, the temperature of the Bragg grating is held constant and the signal reflected at the grating is fed back to the transmitting laser and used to dynamically tune the laser to the reflected wavelength by adjustment  
10 of the laser temperature. However, the provision of a stable temperature environment for the Bragg grating without recourse to adjustment on the basis of variations in the reflected wavelength is difficult to implement and is dependent on the reliability of normally electrical  
15 heating and cooling elements.

In the light of the disadvantages associated with the prior art it is an object of the present invention to provide an arrangement and procedure for controlling the  
20 wavelengths of channels in an optical WDM system which is reliable, simple and inexpensive in its implementation.

#### SUMMARY OF THE INVENTION

25 To control the wavelengths of channels transmitted by one or more optical sources and received by a wavelength selective element, the present invention proposes a method wherein at the receiving end a value of a wavelength influencing parameter of the wavelength  
30 selective element that enables the best reception of the channel is determined. This value is then utilised to ascertain whether the wavelengths used in the link have drifted. This parameter value associated with the channel centre wavelength is accurately located by determining  
35 two parameter values at which the output power drops by a predetermined amount, and then calculating the central value. When the parameter values are difference values relative to a nominal starting value, the mean averaged over all channels serves as an indicator of wavelength

5 drift in the link. By determining the proportion of  
channels demonstrating wavelength drift, both the source  
and magnitude of the wavelength drift can be ascertained  
and corrected either by adjusting the parameter value of  
10 the wavelength selective element or by adjusting the  
wavelength launched by one or more lasers. A wavelength  
control arrangement for use in an optical WDM link  
according to the invention is characterised by control  
means that communicate with a parameter regulator of the  
15 wavelength selective element that is adapted to regulate  
a wavelength influencing parameter and with means that  
monitor the output power of the wavelength selective  
element. The control means are furthermore coupled to a  
regulator adapted to regulate a wavelength influencing  
20 parameter of a laser and laser drive circuit and are  
adapted to determine the magnitude and source of a  
wavelength error and subsequently control one or both of  
the wavelengths launched by the lasers and the  
wavelengths received by the wavelength selective element.

25 Advantageously, the method and arrangement according to  
the present invention permit wavelength drift to be both  
detected and corrected whether caused by one or more  
malfunctioning lasers or by the wavelength selective  
element when the parameter utilised is temperature,  
30 wavelength drift at the wavelength selective element  
could, for example, result from the deterioration of  
associated electrical temperature regulating elements.  
Furthermore, the method obviates the need for permanent  
wavelength references at the optical sources or lasers,  
35 but nevertheless permits wavelength drift to be  
determined and corrected with high precision. The control  
measurement can be performed entirely at the receiving  
end of the link without impeding or degrading normal  
traffic flow. A further advantage of the method and

5 arrangement according to the present invention is that  
the division of the channels received by the wavelength  
selective element does not need to precisely match the  
transmitted wavelengths. The best average power for all  
10 channels can be defined and maintained using the method  
and arrangement according to the invention.

#### BRIEF DESCRIPTION OF THE DRAWINGS

15 Further objects and advantages of the present invention  
will become apparent from the following description which  
describes the preferred embodiments by way of example  
with reference to the accompanying drawings in which:

20 Fig. 1 schematically depicts a 16 channel  
optical wavelength division  
multiplexed system,

25 Fig. 2 schematically shows the control  
system for controlling matching of  
wavelength between the transmitting  
optical sources and the demultiplexer  
filter,

30 Fig. 3 shows the typical transmission  
characteristics of an arrayed  
waveguide grating utilised as a  
demultiplexer filter, and

35 Figs. 4 and 5 show flow diagrams of the procedure  
for determining and correcting  
wavelength shift between optical  
source lasers and the demultiplexer  
filter.

## 5 DETAILED DESCRIPTION OF THE DRAWINGS

10 The WDM link depicted in Fig. 1 includes a plurality of WDM transmitters 10, each adapted to transmit data signals modulated on a specific transmission wavelength. The transmitters 10 each comprise a wavelength specific laser 110 (see Fig. 2) for launching the carrier wavelength. The multiple channels are coupled to a traffic cable 30 by a multiplexer 20 and are sent to the receiving node possibly via a number of amplifiers 40 if  
15 the distance between the nodes is large.

At the receiving node, the channels are split by a demultiplexer filter 50. In the exemplary embodiment the demultiplexer filter is an arrayed waveguide grating (AWG) in silicon dioxide on silicon ( $\text{SiO}_2$  on Si), however  
20 it will be understood that other materials and also alternative wavelength selective elements may be employed. The divided channels are then passed on individual cables to corresponding WDM receivers 80, of which only one is illustrated here for convenience.  
25

The light signals of the individual channels output from the demultiplexer filter 50 are also monitored using detectors 70. One detector 70 only is illustrated in the figure for clarity, however, it will be understood that a  
30 detector 70 will typically be coupled to each outgoing channel. Alternatively, a single detector could monitor the light signals from all outgoing channels in sequence. The detectors 70 can be any optical detector that converts an optical signal into electrical energy such as  
35 a PIN diode detector, and are typically coupled to the optical transmission line using optical taps 60 that divert a small portion of the incident power towards the associated detector 70.



5

The components of the wavelength control system are shown in Fig. 2. In this figure like reference numerals have been used for like elements shown in Fig. 1. The elements include, at the receiving end of the optical link shown in the lower half of Fig. 2, the demultiplexer filter constituted by an arrayed waveguide grating (AWG) filter 50, the detectors 70 coupled to each outgoing channel of the AWG filter 50 by a respective optical tap 60 (here again only one detector 70 and fibre tap 60 are illustrated for convenience), a temperature regulator 90 associated with the demultiplexer filter 50 and a wavelength controller 100. The temperature regulator 90 is a device for varying the temperature of the AWG filter 50 and may comprise a heater, a cooler or a combination of the two, including, but not limited to, resistive heaters and thermoelectric coolers.

The wavelength controller 100, which typically may comprise a microprocessor with associated memory, is coupled to the output of the detectors 70 and the temperature regulator 90. The controller 100 is likewise coupled to each transmitter 10 of the optical link, only one of which is illustrated here, via a service or control channel 150 indicated by a dashed-dotted line in Fig. 2. In each transmitter 10, the controller 100 communicates with a laser drive circuit 140, which supplies bias current to a laser 110 and with a laser temperature regulator 130. The laser is typically a distributed feedback laser (DFB) although it will be understood that other types of laser can also be utilised. The laser temperature regulator incorporates a thermal/cooling element, such as a Peltier element or the like, for varying the temperature of the laser and accordingly adjusting the emitted wavelength. In

5 alternative laser types the emitted wavelength may be controlled by adjusting electrical current to the laser, or by the mechanical movement of optical elements, for example to increase or reduce strain. It will therefore to be understood that appropriate means of adjustment can  
10 be provided to an alternative laser in place of the arrangement described with reference to the figures. The transmitter 10 further includes a modulator 120 for modulating information data on the carrier signal.

15 It should be noted that while in Fig. 2 the controller 100 is shown disposed at the receiving end of the optical link it may also be placed at the transmitting end, in which case it would communicate with the detectors 70 and the temperature regulator 90 at the receiving end via the  
20 service channel 150. Alternatively the controller 100 may be located remote from both ends of the link.

A typical transmission characteristic of a demultiplexer filter 20 suitable for use in an optical WDM link is  
25 shown in Fig. 3. In the example shown, the passband wavelengths correspond to the International Telecommunications Union (ITU) standard wavelengths defined in the 1500 nm telecoms window. It is possible to adjust the passband wavelengths of the filter 20 by  
30 varying the demultiplexer temperature. For an AWG filter in SiO<sub>2</sub> on Si, the variation in passband wavelength is of the order of 0.012nm per degree Celsius. Since the transmission of the demultiplexer is wavelength dependent, the signal power to each detector 70 will vary  
35 with the temperature of the demultiplexer. It is possible to determine the temperature accurately, and in this way to indirectly measure the wavelengths of the incoming channels relative to one another. Specifically, the centre wavelength of a transmitted channel is ascertained

5 by determining the temperature of the demultiplexer filter 50 at which this wavelength is transmitted. In this manner both wavelength drift of one or more individual channels and temperature variation in the demultiplexer can be detected accurately.

10

While the embodiment shown in the figures and described above is applied to the case wherein the passband wavelengths of the demultiplexer filter 50 vary with temperature, it will be understood that other demultiplexer filters may be utilized which have a passband wavelength dependent on other parameters, including, but not limited to electrical injection current or mechanical movement of optical elements. With such a device the determination and measurement of wavelength drift will be achieved by varying the appropriate wavelength influencing parameter of the demultiplexer filter 50. Accordingly the temperature regulator 90 of the demultiplexer filter 50 will be replaced, or supplemented by an appropriate regulator or regulators for varying the parameter of interest. A similar parameter regulator can be employed at the transmitter 10 for adjusting the wavelength of the laser in place of, or in addition to the temperature regulator 130.

30

The method for controlling wavelength using temperature adjustment is described below. It should be noted that for devices with wavelength influencing parameters other than temperature an analogous method could be used.

35

Prior to operating the link the lasers are first adjusted to the desired nominal wavelengths. In an optical WDM network the nominal wavelengths preferably conform to the ITU standard for the 1500nm telecoms window. The

5 adjustment is effected using a well calibrated external  
measuring instrument such as an optical wavelength meter  
or the like. Since the division of the demultiplexer  
filter 50 channels may not exactly match the  
predetermined nominal wavelengths, it may not be possible  
10 to obtain maximum power for all channels at the  
demultiplexer filter 50. To adjust for this eventuality,  
the feedback loop constituted by the controller 100, the  
temperature regulator 90 and the detectors 70 is used to  
set the temperature of the demultiplexer filter 50 to  
15 obtain the optimal mean output power from all utilised  
channels. To this end, the controller 100 performs an  
appropriate step algorithm which adjusts the temperature  
of the wavelength selective element until the mean output  
power from all channels is optimised. Note that the mean  
20 output power need not be the median of the individual  
output powers, but could be weighted to ensure that no  
individual channel falls below a predetermined threshold  
level. It should be noted that in the following method  
the number of channels is indicated by  $n$ . In the  
25 embodiment illustrated in Figs. 1 and 2, therefore,  $n$   
goes from 1 to 16.

Once both the nominal wavelengths and the initial  
temperature have been defined and fixed, the controller  
30 100 calculates the initial variance ( $IV_n$ ) for each  
channel. This value corresponds to the difference between  
the temperature of the selective element when it  
transmits the optimum mean power of all channels and its  
temperature when it transmits a single channel optimally.  
35 The initial variance value ( $IV_n$ ) for each channel is  
obtained using the procedure A illustrated in Fig. 4. In  
step 401 the starting temperature of the wavelength  
selective element, which in this case is the temperature  
for optimal average transmission of all nominal

5      wavelengths, and the power level of each channel is stored. The starting temperature may be an absolute temperature value, but it is preferable that this temperature be set to a nominal value, e.g. 0. The temperature of the demultiplexer filter 50 is incremented  
10      in step 402. In step 403 the power level of each channel at the output of the demultiplexer filter 50 is compared with the initial output power. If it has fallen below 0.5dB, the temperature is stored (step 405) if not, the method returns to step 402 and the temperature of the  
15      demultiplexer filter 50 is incremented again. This continues until the power levels of all channels have fallen below the 0.5dB level and the corresponding temperatures of the demultiplexer 50 is stored. In practice the stored temperatures will be quantized values  
20      corresponding to the number of temperature increments. The demultiplexer filter 50 is then returned to the starting temperature in step 405. In step 406, the temperature of the demultiplexer filter 50 is decremented. In step 407 the output power level of each  
25      channel is measured and compared with the initial power level to determine whether it has dropped by 0.5dB. If not, the method returns to step 406, otherwise, the corresponding temperature is stored. This continues until two temperature values (D<sub>Hn</sub> and D<sub>Ln</sub>) corresponding to the  
30      -0.5dB power levels have been determined for all channels. The mean IV<sub>n</sub> of these two values (D<sub>Hn</sub>, D<sub>Ln</sub>) for each channel computed in step 409 then corresponds to the difference in temperature of the demultiplexer filter 50 for transmitting the mean optimal power of all channels  
35      and the optimal power of the channel in question when the channels are tuned to the predetermined nominal wavelengths. By inference, this mean variance value IV<sub>n</sub> likewise corresponds to the initial wavelength error for each channel. The mean value IV<sub>n</sub> is then stored for each

5 channel in the controller 100 for use in the subsequent wavelength checks.

10 When the temperature values ( $DH_n$ ,  $DL_n$ ) are difference values relative to the starting temperature, then, providing the centre wavelength of the filter 50 lies within the 0.5dB levels of the actual launched channel, one value  $DH_n$  will be positive and the other  $DL_n$  negative. Accordingly if the launched centre wavelength is exactly equal to the centre filter wavelength, the  
15 initial variance value  $IV_n$  will be zero. Note that since the temperature of the demultiplexer filter 50 has been adjusted for optimal average output power for all channels, the mean of these variance values  $IV_n$  for all channels will be zero at this stage.

20 The initial starting temperature of the demultiplexer 50 determined as described above is the ideal operating temperature and is consequently maintained using conventional electrical thermal and cooling elements and  
25 a suitable control circuit which is not shown. With time, however, these electrical elements may deteriorate, causing the real temperature of the demultiplexer filter 50 to vary and hence the passbands of the filter 50 to shift in wavelength. Errors leading to drift in  
30 wavelength may also arise in individual lasers 110.

Hence, during operation of the optical WDM link the correlation between the launched wavelengths and the wavelengths transmitted through the demultiplexer filter  
35 50 is checked at regular intervals using the procedures laid out in Figs. 4 and 5. Firstly, steps 401 to 409 of procedure A are followed as described above with, in this case, the starting temperature being the actual temperature of the demultiplexer filter 50 at the time of

5 measurement, and the mean of the difference values  $DH_n$  and  $DL_n$  being a channel mean value  $MCD_n$ , i.e. the mean of the difference values  $DH_n$  and  $DL_n$  for each channel relative to the actual temperature. The method then goes on to procedure B shown in Fig. 5. In step 501 the  
10 average MD of all channel mean values  $MCD_n$  is calculated. This average value is computed on the same basis as the initial average output power of all channels and accordingly may be weighted if the initial distribution of channel wavelengths in the AWG filter rendered this  
15 necessary. Accordingly if no wavelength drift has occurred on the link, i.e. if the wavelengths launched by the lasers 110 and the temperature of the demultiplexer filter 50 are unchanged, the average mean MD will be zero. In this case the comparison in step 502 results in  
20 an answer YES and the procedure is terminated. However, if this value is not equal to zero, wavelength drift must have occurred, as a result of an error either in one or more lasers or the temperature regulation of the demultiplexer filter 50, or a combination of both of  
25 these. The procedure then continues in step 503, where for each channel the initial variance value  $IV_n$  is compared with the determined mean value  $MCD_n$ . This step determines the number of individual channels whose wavelength has varied with respect to the initial value.  
30 The sum of these comparison results which deviate from zero is then compared with a predetermined value P in step 504 to determine the proportion of channels which have varied with respect to the initial settings. Since it is unlikely that all lasers 110 will fail  
35 simultaneously, a majority of deviating channel wavelengths will indicate that the temperature of the demultiplexer filter 50 has altered. Accordingly, The value P is selected to represent a failure in the majority of the channels used, or at least in the

5 proportion of the used channels which statistically are unlikely to fail simultaneously. It may not be necessary to perform the comparison of step 503 for all channels. If at least a predetermined number of comparisons is performed, this will enable the accurate determination of  
10 how widespread any wavelength drift is, and accordingly give an indication as to whether the temperature of the lasers 110, the demultiplexer filter 50 or both need adjusting to correct the wavelength.

15 If fewer channels than P have drifted from the initial wavelengths, then the method turns to step 505 where, for each channel, the channel mean values MCDn are used to correct the wavelengths launched by the corresponding lasers 110, preferably by altering the temperature using  
20 the regulator 130. Conversely, if the result of the comparison in step 504 is YES, the method continues to step 506 where the common deviation of the channels is determined. This value is then used in step 507 to correct the temperature of the demultiplexer filter 50. Once the error caused by the demultiplexer filter 50 has  
25 been corrected, the channel mean values MCDn are corrected in step 508 by subtracting the common value determined in step 506. The corrected MCDn values are then used in step 505 to correct the wavelengths launched by the lasers, if necessary.  
30

This procedure can, for example, be performed once every month since it is primarily adapted to detect long variations in wavelength. The procedure can also be  
35 carried out during normal traffic operation without deterioration of payload traffic. To this end, the temperature increments used in method A in Fig. 4 are selected to obtain a reasonable variation in wavelength of the light signals transmitted by the demultiplexer



5 filter without unduly attenuating the received signals or  
provoking crosstalk in adjacent channels. For example,  
for an AWG demultiplexer filter in SiO<sub>2</sub> on silicon,  
increments of 1 °C resulting in a stepwise variation in  
transmitted wavelength of 0.012nm is acceptable. It  
10 should further be noted that the output power reduction  
of 0.5dB is also given only by way of example. This value  
is similarly chosen to permit accurate but easily  
measurable wavelength variations without disturbance to  
traffic by attenuation or crosstalk.

15 In an alternative embodiment of the invention steps 503  
and 504 in the method B of Fig. 5 are replaced by a  
single step wherein the mean variation for all channels  
MD is compared with a predetermined fixed value. This  
20 value is selected according to the number of channels  
utilised and relies on the fact that a wavelength drift  
due to a variation in temperature of the demultiplexer  
filter 50 will result in a total mean variation n times  
as large as the same drift in a single laser when n  
25 channels are used. Since it is highly improbable that one  
or more lasers will vary in wavelength to a degree which  
results in the same mean value, or that their wavelengths  
vary to an extent that cancels out a variation caused by  
the demultiplexer filter temperature, a predetermined  
30 fixed value can be selected to provide a reasonably  
accurate gauge as to the source of the wavelength drift.

In a further embodiment of the invention, the processing  
step 508 can be omitted and in its place the whole method  
35 starting from step 401 of procedure A be repeated. Since  
the drift caused by a temperature variation in the  
demultiplexer has been corrected, a repeat of the whole

5        method will result in the correction of the wavelengths  
launched by the lasers, if necessary.

10        The aforementioned method is particularly well adapted  
for use in an optical WDM system where pre-defined  
wavelengths are used, however, it also has application in  
optical WDM point-to-point links where the standards laid  
down for wavelengths need not be respected. In such a  
point-to-point link, the method described with reference  
to Fig. 4 can be used to accurately match the wavelengths  
15        launched by the lasers 110 to the wavelength division of  
the demultiplexer filter 50 and so enable optimal  
transmission over all channels.

5

## CLAIMS

10 1. A method for controlling the wavelength of a plurality of channels launched by optical transmission means and received by at least one wavelength selective element in an optical WDM link, the method including:

15 noting a starting value of a wavelength influencing parameter of said wavelength selective element,

20 for each channel, determining a channel centre value (MCDn) of said parameter of said wavelength selective element at which the output power of said channel is a maximum,

25 utilising said channel centre values (MCDn) to determine a deviation between said launched wavelengths and wavelengths selected by said wavelength selective element and to correct said wavelength deviation at at least one of said wavelength selective element and said optical transmission means.

30 2. Method as claimed in claim 1, wherein determining said channel centre values includes

35 for each channel, determining a first parameter value (DHn) of said wavelength selective element relative to said starting parameter value at which the power of said channel output from said wavelength selective element falls below a predetermined level,

for each channel, determining a second parameter value (DLn) of said wavelength selective optical element.

5 relative to said starting value at which the power of  
said channel output from said wavelength selective  
optical element falls below said predetermined level, and

10 for each channel, determining a channel mean value (MCDn)  
corresponding to the average of said first and second  
parameter values.

15 3. A method as claimed in claim 2, wherein said first  
and second parameter values are difference values (DHn,  
DLn) relative to said starting value.

20 4. A method as claimed in any one of claims 1 to 3,  
including calculating a mean value (MD) corresponding to  
the average of said channel centre values (MCDn) for all  
channels, and

25 utilising said mean value (MD) as an indicator of  
wavelength drift in said optical link and to adjust a  
deviation between said launched wavelengths and  
wavelengths selected by said wavelength selective element  
in said channels.

30 5. Method as claimed in claim 4, including utilising  
said channel centre values to determine the proportion of  
channels which manifest a drift in wavelength relative to  
the total number of channels, and

35 utilising said mean value (MD) to adjust a wavelength  
influencing parameter of said wavelength selective  
element when said proportion exceeds a predetermined  
amount.

5       6. A method as claimed in any one of claims 1 to 5,  
including:

for each of at least a predetermined number of channels  
comparing said channel centre value (MCDn) with a  
10       predetermined channel variance value (IVn) to obtain a  
difference value (Dn) indicative of a wavelength shift in  
said channel..

7. A method as claimed in claim 6, including determining  
15       the proportion of said channels which demonstrate a  
wavelength drift by summing the difference values (Dn)  
that deviate from zero for at least a predetermined  
number of channels.

20       8. A method as claimed in claim 6 or 7, including setting  
said predetermined channel variance value (IVn) as a  
difference between a value of said parameter of said  
wavelength selective element at which the output power of  
said channel having a predetermined nominal channel  
25       wavelength is optimised and a value of said parameter of  
said wavelength selective element at which the average  
output power of all channels having predetermined nominal  
wavelengths is optimised.

30       9. A method as claimed in any one of claims 6 to 8,  
including:

prior to operation of said optical link, setting the  
wavelengths of the optical transmission sources to  
35       predetermined nominal wavelengths,

setting said wavelength selective element to a nominal  
parameter value at which the output power of all said  
channels is optimised,

5

for each channel, determining a first value of said parameter of said wavelength selective element relative to said nominal value at which the power of said channel output from said wavelength selective element falls below a predetermined level,

10

15

for each channel, determining a second parameter value of said wavelength selective optical element relative to said nominal value at which the power of said channel output from said wavelength selective optical element falls below said predetermined level,

20

for each channel determining the mean of said first and second parameter values, and

for each channel, utilising said mean as said predetermined channel variance value (IVn).

25

10. A method as claimed in one of claims 6 to 9, including utilising said difference values (Dn) to adjust a wavelength influencing parameter of said wavelength selective element.

30

11. A method as claimed in one of claims 6 to 9, including for each channel utilising said difference value (Dn) to correct the wavelength launched by said optical transmission means.

35

12. A method as claimed in any one of claims 3 to 11, wherein said mean value (MD) is a weighted average of said first and second parameter values for all channels.

5 13. A method as claimed in any one of claims 1 to 12, characterised in that said parameter is the temperature of said wavelength selective element.

10 14. A method as claimed in any one of claims 1 to 12, characterised in that said parameter is an electrical injection current into said wavelength selective element.

15 15. A method as claimed in any one of claims 1 to 12, characterised in that said parameter is a mechanical movement of an optical element associated with said wavelength selective element.

20 16. A wavelength control arrangement for controlling the wavelengths of channels utilised in an optical WDM link including

a wavelength selective element (50) for receiving a combined optical signal including a plurality of optical channels launched by optical transmission means (10, 110) and adapted to separate at least two optical channels according to wavelength,

30 monitoring means (60, 70) for detecting optical signals on said channels output from said wavelength selective element (50), and

means for regulating a wavelength influencing parameter (90) associated with said wavelength selective element (50) for regulating said parameter of said wavelength selective element,

35 characterised by

5 control means (100) arranged to communicate with said  
regulator (90) and said monitoring means (70) and adapted  
to determine a parameter value of said wavelength  
selective element (50) for each channel relative to a  
10 starting parameter value of said wavelength selective  
element (50) at which the output power of said channel is  
a maximum, to determine a wavelength drift on the basis  
of said parameter values and to generate at least one  
control signal for rectifying wavelength.

15 17. An arrangement as claimed in claim 16, characterised  
in that said control means (100) are adapted to determine  
two parameter values associated with said wavelength  
selective element (50) for each channel at which the  
output power of said channel falls below a predetermined  
20 level.

18. An arrangement as claimed in claim 16 or 17,  
characterised in that said control means (100) comprise  
processing means for determining the magnitude and source  
25 of said wavelength drift.

19. An arrangement as claimed in any one of claims 16 to  
18, characterised in that said wavelength selective  
element (50) is an arrayed waveguide grating (AWG).  
30

20. An arrangement as claimed in any one of claims 16 to  
19, characterised in that said control means (100) are  
adapted to communicate with said optical transmission  
means (10) to alter the launched wavelength using said at  
35 least one control signal.

21. An arrangement as claimed in any one of claims 16 to  
20, characterised in that a regulator (130) associated  
with a laser (110) in said transmission means (10) is



5 adapted to vary a wavelength influencing parameter of said laser (110) in response to at least one control signal from said control means (100).

10 22. An arrangement as claimed in any one of claims 16 to 21, characterised in that said regulating means (90) are adapted to vary said parameter of said wavelength selective element (50) in response to at least one control signal from said control means (100).

15 23. An arrangement as claimed in any one of claims 16 to 22, characterised in that said control means (10) are adapted to communicate with at least one of said transmission means (10) and said regulating means (90) and monitoring means (70) via a control channel 150.

20 24. An optical WDM link comprising a wavelength control arrangement as claimed in any one of claims 13 to 23.

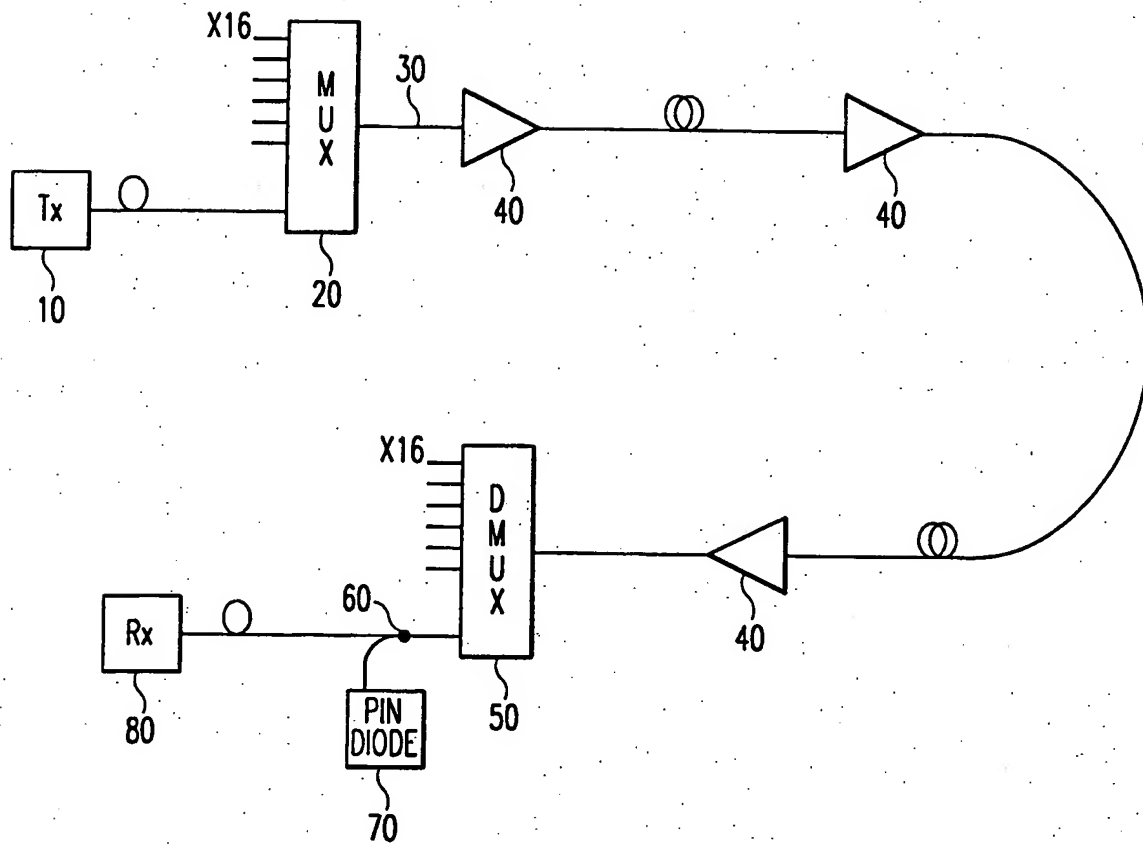


Fig. 1

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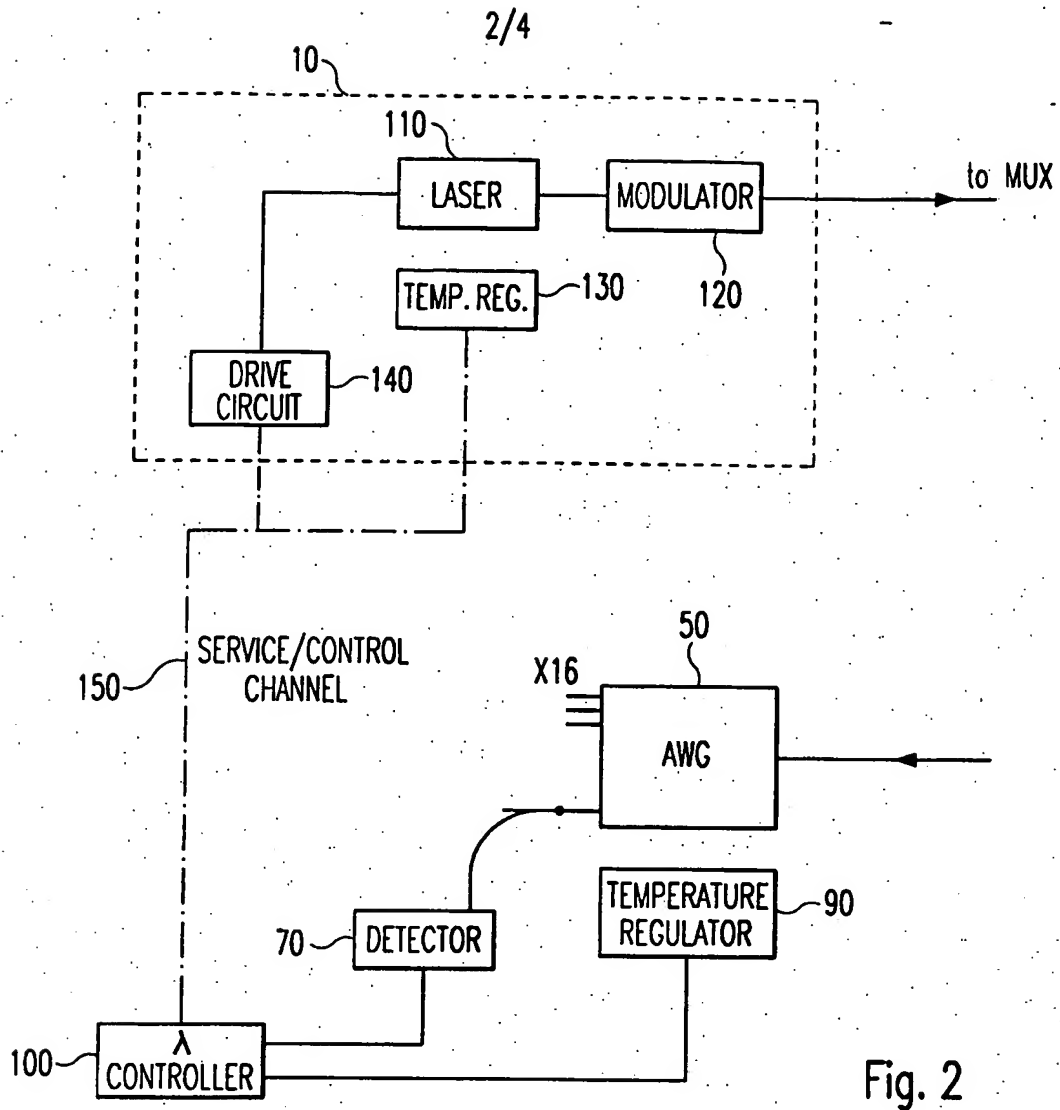


Fig. 2

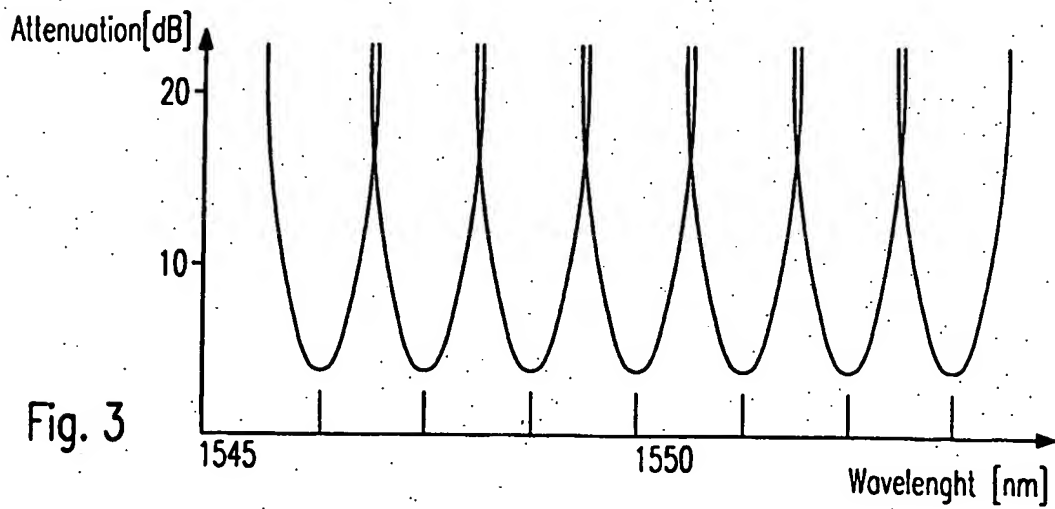


Fig. 3

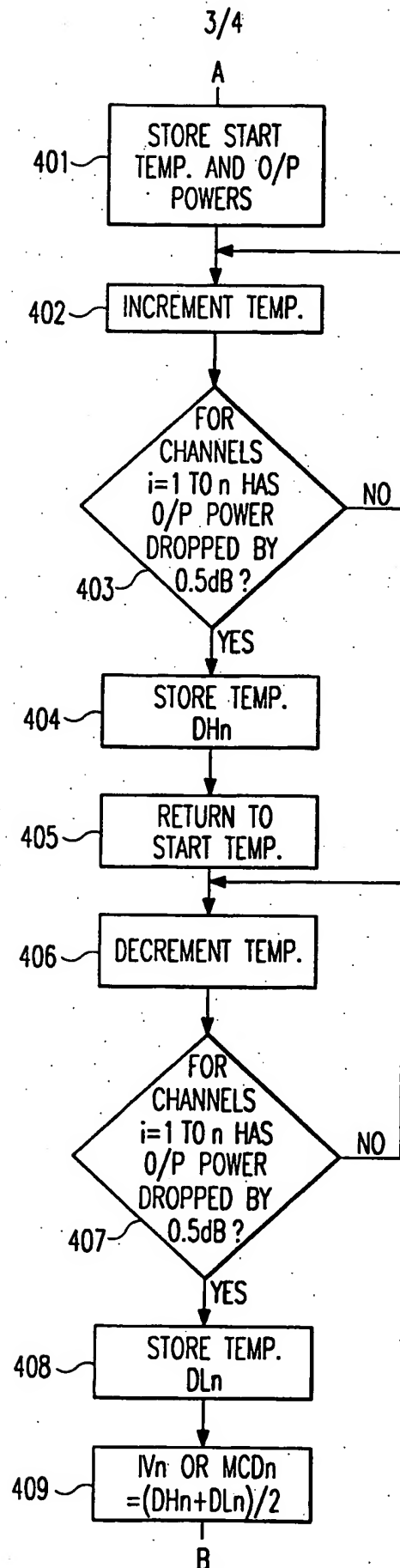


Fig. 4

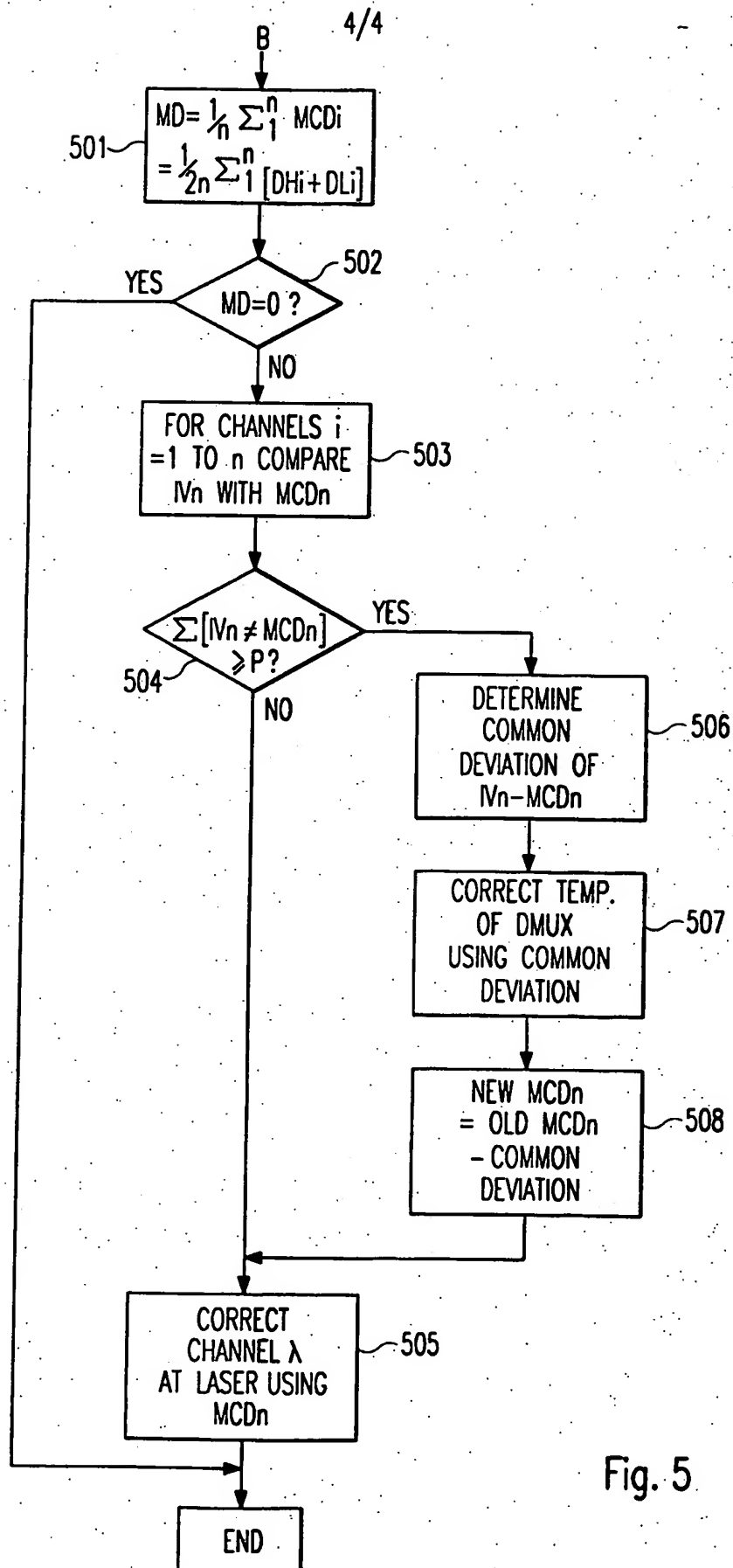


Fig. 5